ARSENOTUNGSTIC ACID AS AN ALKALOIDAL REAGENT

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CHEMISTRY

COLLEGE OF LIBERAL ARTS AND SCIENCES

UNIVERSITY OF ILLINOIS

1922

UNIVERSITY OF ILLINOIS

May 24, 1922 192

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED Arsenotungstic Acid as an Alkaloidal Reagent.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science, in Chemistry.

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ACKNOWLEDGEMENT

I wish to take this opportunity of expressing my sincere thanks to Dr. George Denton Beal, who, by his good will and invaluable assistance has made this investigation a success.

Edwin R. Littmann

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HISTORICAL OUTLINE

Many complex metallic acids yield precipitates with organic bases. The best known example is the precipitation of an ammonium salt of phosphomolybdic acid, $(NH_4)_3PO_4.12MoO_3$, when ammonium molybdate is added to a solution of phophoric acid, as the first step in the determination of phosphorus from practically all sources. The use of phosphomolybdic acid has since that time been extended to the precipitation of more complex bases. Phosphotungstic* acid has been used to a much greater extent in this way than has phophomolybdic acid. The especial value of phophotungstic acid lies in its use in the separation of the protein and non-protein forms of nitrogen, as a substitute for the copper hydroxide reagent of Stutzer.[1]

Bertrand[2] has prepared a series of silico-tungstic acids of which one form of the silico-duodecitungstic acid, $4H_2O$, SiO_2, $12WO_3$, $22H_2O$, has been used successfully by the Chapin[3] method for the determination of nicotine. Further studies of silico-tungstic acid as an alkaloidal reagent have been made by Beal and Peterson[4] and by Buch and Beal[5]. These reagents have shown so much promise that it has been decided to study the behavior of other complex metallic acids, including the arseno-tungstic acids, with particular reference to their availability as precipitating reagents for alkaloids.

Chemical literature yields little on the subject of arsenotungstic acids. Among the references to the preparation of various forms of the acid so far mention has only been made twice to the reactions of arsenotungstic acids with organic compounds. These are to the work of S.R. Benedict[6] and Morris Macleod[7] on the reaction between arsenotungstic acid and uric acid. Arsenotungstic acid has been suggested as a reagent for the determination of uric acid, based upon the reducing action of the uric acid on the tungsten. It was found that uric acid reduced the arsenotungstic acid to "tungsten blue". From this has been developed a colorometric method for uric acid. The reaction, however, does not depend upon the formation of a complex molecule containing the compounds. In neither of the two articles above was any attempt made to isolate the acid or any of its salts. The authors state that the composition of the acid was unknown. In 1888 an article was published by Gibb[8] on the preparation of arsenotungstic acids according to the method of Fremery. Gibbs, in his own work obtained a salt of the following composition: $16WO_3.As_2O_5.6Ag_2O\ \ 11H_2O$. The method of Gibbs is as follows:- To an aqueous solution of arsenic acid add freshly precipitated barium tungstate, followed by sulphuric acid to decompose the barium tungstate. Filter the mixture and evaporate on the water bath until crystals just form. Remove the dish and allow to cool. The precipitate is a mixture of two acids alpha and beta.

Dissolve this precipitate in boiling water. Add Potassium chloride to form the potassium salts. A precipitate should separate immediately. Allow the solution to cool, when yellow prisms should deposit. As soon as this occurs decant the liquid. The two products so obtained must be recrystallized until pure. The first precipitate is the alpha and the second the beta salt.

The formulae are: alpha $As_2O_5.9WO_3.14H_2O$

beta $As_2O_5.18WO_3.XH_2O$

Since 1888 no satisfactory method for the preparation of an acid of definite composition has been published. It is true that quite a number of acids have been prepared, but there is doubt as to their composition, yields and methods of preparation. With but one exception the preparation of the acids involved such proceedures as fractional crystallization to separate the various compounds formed. Kehrman[9] in 1900 published a paper on the preparation of an arsenotungstate of definite composition. His method is as follows:- To a saturated solution of sodium-tungstate add "syrupy" arsenic acid until the solution is distinctly acid, then one half as much again. Finally add solid ammonium chloride to precipitate the ammonium arsenotungstate. The product must be purified by repeated salting out. It has the formula $3(NH_4)_2O. As_2O_5.18WO_3.14H_2O$.

This method was used as a starting point.

THEORETICAL CONSIDERATION.

There is no definite theory to account for the combination of arsenic acid and a tungstate to form a complex. In view of this lack the condition of the experiments must be closely followed in order to duplicate results. The method of Kehrman[4] was modified in an attempt to get better yields of the pure salt. The modification changed only the method of precipitation. Instead of saturating the solution with ammonium chloride and immediately filtering the product, the salt was added until a precipitate just formed and then allowed to stand. At the end of twenty four hours a very crystalline precipitate will have been deposited. This precipitate is a pure salt, as purification by salting out with ammonium chloride twice gave no changes in the analysis.

When an attempt was made to analyze the salt for arsenic many difficulties had to be overcome before concordant results could be obtained. The arsenic was precipitated as magnesium ammonium arsenate, but even after three precipitations the ignited residue showed the presence of tungstic oxide (WO_3).

An electrolysis of a solution of the ammonium arsenotungstate caused violent "popping" but no liberation of arsine. This "popping" and the fact that the salt changed color but did not decrepitate at 100° C. led to a further investigation as to its physical properties. The salt was placed in a dilatometer and the bulb heated slowly to 110° C. The heigth of the column

(Mijol) was read for each degree rise in temperature. The curve (Figure I.) shows that there is a transition point at 97^{o} - 98^{o} C. At study of the changes in crystal structure further advances the probability of meta-stability. A sample of the dry salt when placed on a heated microscope (Figure 3) stage changes in color from yellow to green as soon as the temperature reaches the transition point, but the change is crystal structure is not so rapid. If, however, a drop of water is added to the sample on the stage the crustal change occours as soon as the water has evaporated. Figure two shows the original salt (a) and after treatment with water and heat (b).

The failure of the arsenic precipitation can be laid to the meta stable compound being present to some extent if we assume that the meta stable compound will not give up its arsenic as readily as the stable material.

It was then decided to decompose the complex by reducing the arsenic and distilling the arsenous chloride ($AsCl_3$). The most effective reducing agent found was titanous chloride ($TiCl_3$). Hydrogen sulfide reduces the compound and precipitates arsenous sulphide (As_2S_3) only under pressure and at high temperature. Sulfur dioxide has no effect. Zinc and hydrochloric acid reduces the arsenotungstate but with no evolution of arsine, (AsH_3). Electrical reduction partly deposits metallic arsenic but does not liberate arsine. The accompanying sketch shows the type of apparatus used. The distillate should not come in contact with any rubber because of the presence of sulfur therein.

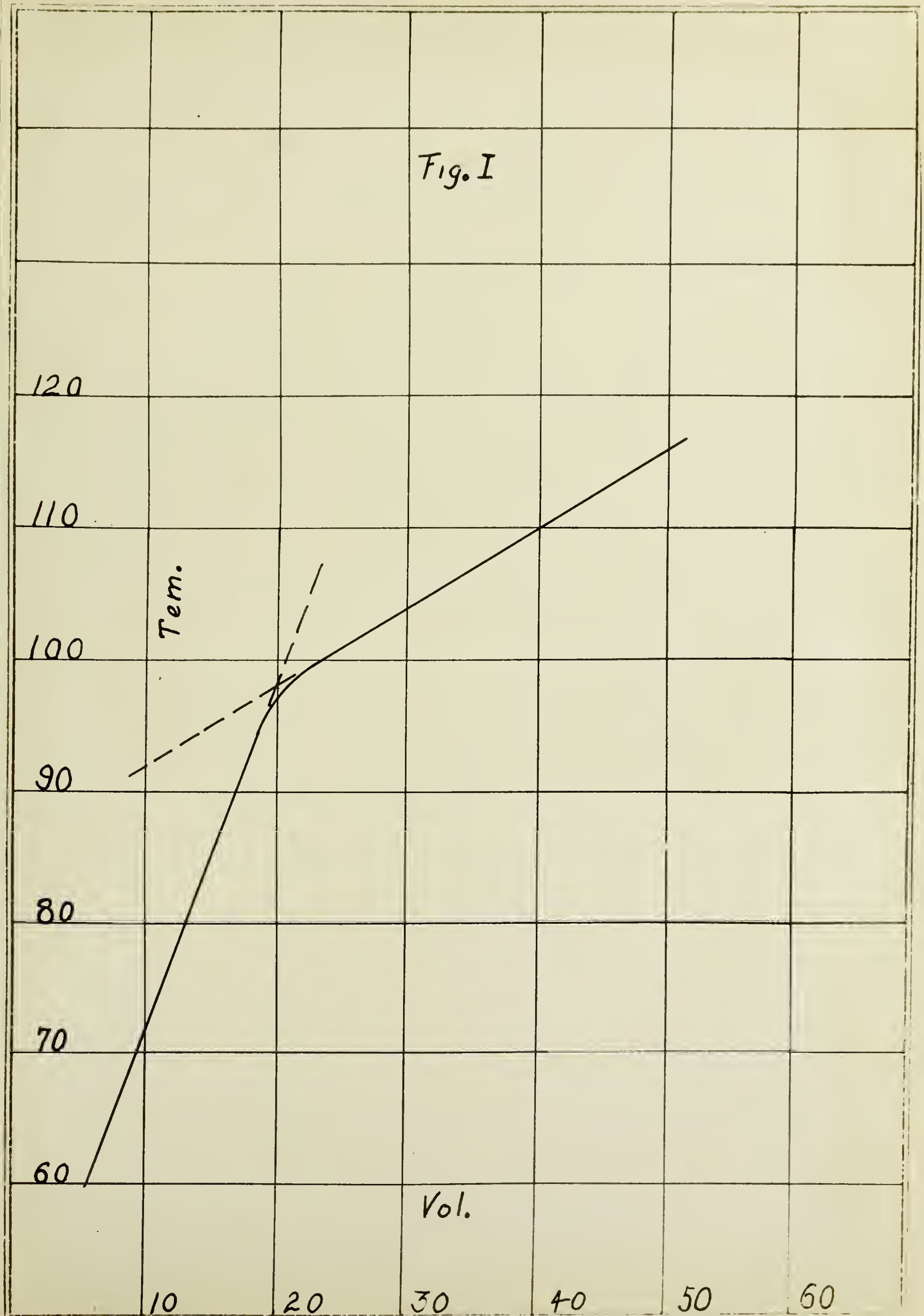
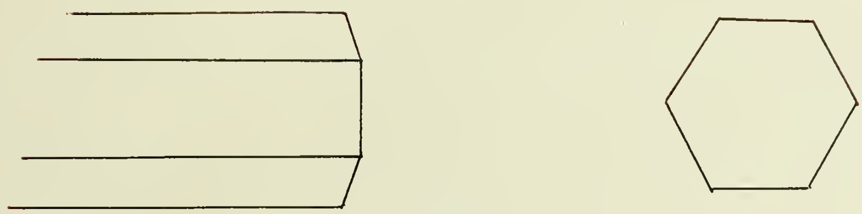
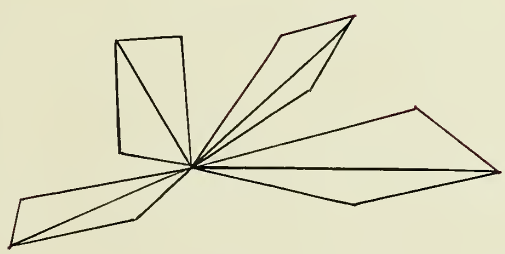


Fig. I
Tem.
Vol.
120
110
100
90
80
70
60
10
20
30
40
50
60

Fig. 2

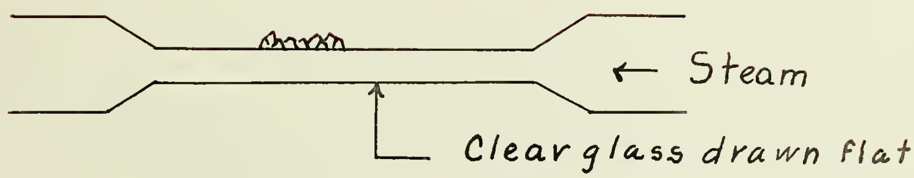


a

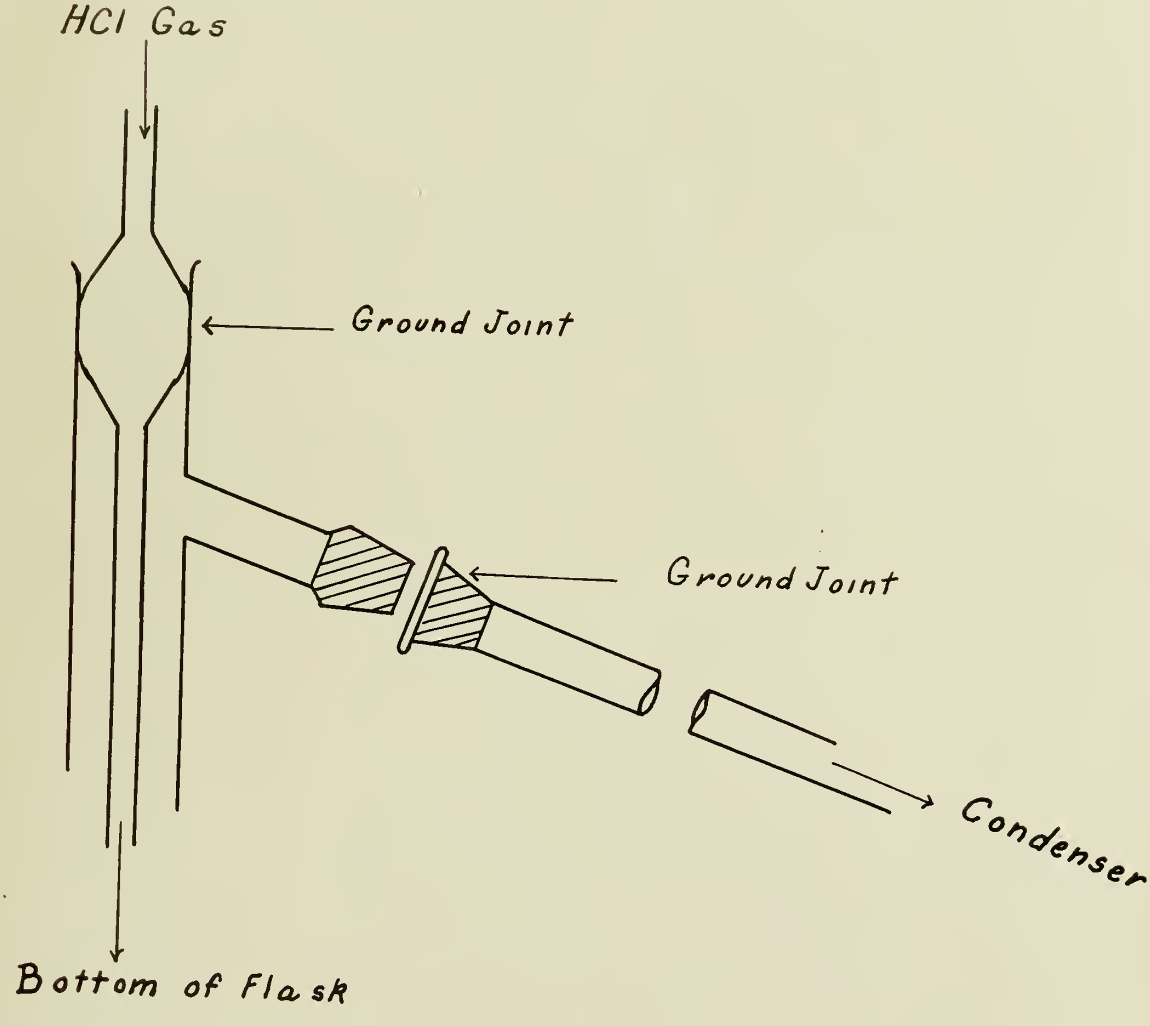


b

Fig. 3



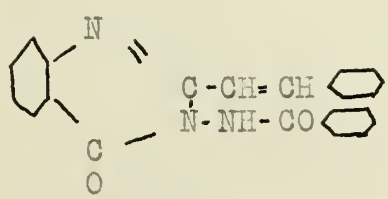
$AsCl_3$ Distillation Flask

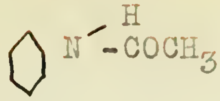
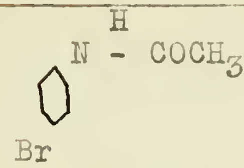
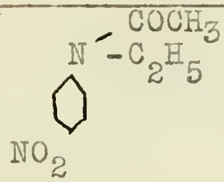
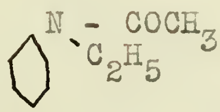
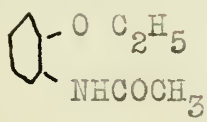
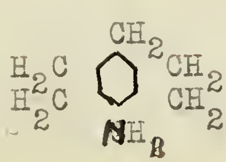


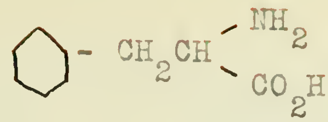
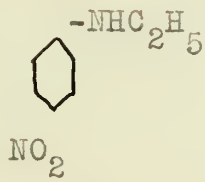
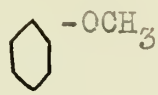
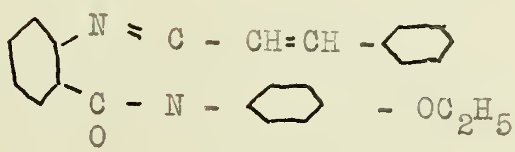
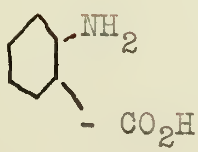
The results of the arsenic analysis, by precipitation, are probably low, as five precipitations were made to free it from tungsten.

As previously stated there are only two references to the reactions of arsenotungstic acid with organic compounds and both of these refer to uric acid only. The present investigation was undertaken in the hope that the arsenic-tungsten combination would behave in the same manner as the silico-tungsten, phosphotungsten, and phospho-molybdenum compounds. In order to test the arseno-tungstate, qualitative analyses were made upon quinine, quinidine, chincholine, and cinchonidine. Other organic nitrogen compounds were also used and the results recorded in the following table.

Note: + reaction
− no ''

Compound	Formula	Reaction
Quinine		+
Quinidine		+
Chinchonine		+
Cinchonidine		+
2 Styryl 3 Benzoyl amino 4 Quinazolone		−

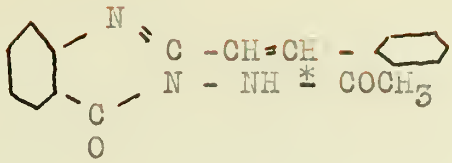
Acetanilide		—
p-Brom Acetanilide		—
p-Nitro ethyl Acetanilide		—
Ethyl Acetanilide		—
Phenacetin		—
Isobutyl Alcohol	$\begin{matrix}CH_3\\CH_3\end{matrix}>CH-CH_2OH$	—
Secondary Butyl alcohol	$CH_3CH_2\overset{OH}{CH}-CH_3$	—
Pyridine		+
Quinoline		+
Piperidine		+

Phenyl amino Propionic acid		−
Trimethyl Amine	$(CH_3)_3N$	+
p-Nitro ethyl Analine		−
Anisole		−
Phenyl amino Thiazole	C S H- C N C - NH_2	+
2 Styryl 3 Phenetedyl 4 Quinazolone		−
Anthranilic Acid		−
Uric Acid	H - N - C = O O = C C - NH C = O H - N - C - NH	−

2 Styryl

3 Acetamine

4 Quinazolone



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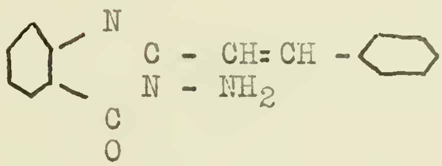
2 Styryl

3 Amino

4 Quinazolone



+

After determining the extend of the possibilities in the qualitative precipitation of the alkaloids, the next step was the determination of the "factor" to be used in quantitative work. The "factor" is explained by the equation: Wt. WO_3 x "factor" Wt. alkaloid. The general method for the determination of the "factor" follows: Dissolve the alkaloid in dilute sulphuric acid with a slight excess. Add an excess of the arsenotungstate solution (1 c.c. ‾ .01 gm.) and heat to boiling. Filter hot and wash thoroughly with hot water. Ignite the filter and precipitate in a weighed crucible at a low red heat and weigh as tungstic oxide (WO_3). The "factors" for the four above mentioned aldaloids are:-

Quinine ------------------ .22565

Quinidine ---------------- .30638

Cinchonine --------------- .24268

Cinchonidine ------------- .26341

In each case the quantitativeness of the precipitation was tested by the standard methods of alkaloid extraction after decomposition of the precipitate by sodium or potassium hydroxide.

The following table shows the results.

Alkaloid	Weight taken	Weight recovered
Quinine	.01985	.02005 (Mean)
Quinidine	.02503	.02498
Cinchonine	.02497	.02491
Cinchonidine	.02772	.02764

EXPERIMENTAL

Preparation of the Ammonium arsenotungstate

To 200 c.c. of saturated solution of crystallized sodium tungstate ($Na_2WO_4 \cdot 2H_2O$)(approximately 85 grams) add 80 c.c of f freshly prepared arsenic acid. (H_3AsO_4) with constant stirring. The temperature of the solution will rise appreciably. Cool the mixture to 25° C. and add 40 gm. of ammonium chloride (NH_4Cl) with stirring. Continue to stir rapidly for 15 minutes and allow the mixture to stand 24 hours. Filter the mixture with suction and centrifuge the crystals until dry. The compound prepared in this way needs no further purification.

Several trials were made using commercial arsenic acid (80%) but a discolored product always resulted. The arsenic acid used was prepared as follows:- To 500 c.c of concentrated nitric acid (C.P.) add arsenous oxide (As_2O_3)in 10 gm. portions with stirring until no further reaction takes place. Filter through an asbestos mat and use as soon as possible. The above reaction proceeds as follows:-

$$2H_2O \quad As_2O_3 \quad 2HNO_3 \qquad 2H_3AsO_4 \quad NO \quad NO_2$$

ANALYSIS of the Salt

Ignite a sample (.2 - .5 gm.) at the lowest possible red heat to contant weight. The residue is WO_3.

Tungsten

Sample	.1449	.1765
Crucible WO_3	10.0905	9.5952
'' along	9.9675	9.4461
WO_3	.123	.1491
	84.8%	84.5%

Place a sample (.5 - 1.0 gm.) in a distilling flask (See sketch) and add 100 c.c of hydrochloric acid (20%). Shake until the material is dissolved then add 50 c.c of titanous chloride solution (15%). Distil the solution in a current of cydrogen chloride. Neutralize the distillate with solid potash (KOH) using phenolphthalein as indicator. Just acidify with hydrochloric acid and again neutralize with sodium bicarbonate ($NaHCO_3$) and add 5 gm. in excess. Titrate this solution with standard iodine using starch as an indicator.

Arsenic

Sample	.3488	.1252
C.c. I soln(.1668)	1.13	.47
As_2O_5 (%)	3.52%	3.50%

The ammonia was liberated with sodium hydroxide and distilled in a Kjeldahl apparatus.

Ammonia

Sample	2.4038	2.6769
C.c. acid(.1053)	25.70	37.0
C.c.alkali(.0971)	.00	7.62
$(NH_4)_2O$	2.935%	3.00%

From the above analyses the following ratios were obtained:-

(1) $As_2O_5:WO_3$ 1:24.18

(2) $(NH_4)_2O:As_2O_5$ 3:78:1

(3) $H_2O:As_2O_5$ 32.2:1

These ratios show the following formula for the ammonium arsenotungstate: $4(NH_4)_2O.As_2O_5.24WO_3.32H_2O$. The specific gravity of the salt was determined by displacement of ligroin and was 5.343 referred to water.

Determination of the "factors"

Dissolve the alkaloid salt in water (or just enough 10 % sulfuric acid if the free alkaloid is used) and add 5 c.c. of 10% sulfuric acid. To this solution add an excess of arsenotungstate solution and heat to boiling. Filter hot and wash the precipitate thorougly with boiling water. When the excess water has drained off place the wet filter in a weighed crucible and ignite very slowly, never allowing the paper to more than glow. When the paper has been thoroughly charred ignite at a faint red heat to constant weight (WO_3). The following results were obtained.

Data on Factors

Quinine

Quinine Hydrochloride	.01985	.01985
Dish and Residue	25.6411	22.4086
Dish alone	25.6250	22.3920
Residue	.0161	.0166

Factor .2256

Quinidine

Quinidine Sulphate	.025035	.025035
Dish and Residue	10.1455	9.5819
Dish alone	10.0565	9.4925
Residue	.0890	.0894
Factor .3064		

Cinchonine

Chinchonine Hydrochloride	.02497	.02497
Dish and Residue	9.5755	9.5316
Dish alone	9.4828	9.4390
Residue	.0927	.0926
Factor .24268		

Cinchonidine

Cinchonidine Hydrochloride	.02772	.02772
Dish and Residue	9.5329	9.6789
Dish alone	9.4394	9.5852
Residue	.0935	.0937
Factor .2634		

Qualitative Tests on Organic Compounds

The compounds were dissolved in a solvent common to the reagent and the compound and acidified with dilute sulfuric acid.

Further Studies on Arseno-tungstic Acid

The arsenotungstate when treated in aquous solution with ammonium carbonate precipitates a white, crystalline product. This material was not analyzed for arsenic but showed 83.7% WO_3.

If the mixture of arsenic acid and sodium tungstate is saturated with ammonia (NH_3) a white amorphous compound precipitates. It contains about 66.5% WO_3.

The tungsten in the $24WO_3$ compound is not precipitated with acids until the arsenic is removed. This indicates a stable complex.

When electrolyzed so as to theoretically release the arsenic as arsine a solution of the arsenotungstate turns blue but gives no arsine. When the same solution is treated in the same way but with the cathode in a porus cup metallic arsenic is partially precipitated.

Sulphur dioxide will not reduce the arsenic or tunsten. Hydrogen sulphide causes reduction only at 100° C., and under pressure;(a pressure flask was used).

Iron salts cause a blue-green coloration in an acid solution of the salt.

SUMMARY of WORK.

A rapid method for the preparation of an ammonium arsenotungstate has been devised. The salt has a definite composition, $4(NH_4) . As_2O_5 . 24\ WO_3 . 32H_2O$.

The ammonium arsenotungstate precipitates certain definite alkaloids. Other organic nitrogen compounds are precipitated by the reagent, but only when apparently, the basicity reaches a definite point.

A method has been devised whereby alkaloids may be quantitatively determined through the use of ammonium arsenotungstate.

Some properties of the ammonium arsenotungstate have been investigated and the results recorded.

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